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Pumped hydro storage in federal waterways

An evaluation of potentials for Germany

November 12th, 2012 | Peter Stenzel, Ewgenij Kossi

Outline

- Introduction
- Methodology for the potential evaluation
- Results
- Summary and Outlook

Introduction

Present situation

- 32 pumped storage plants in Germany with a storage capacity of approx. 6.4 GW, 40 GWh

Increasing storage demand in the future due to the transformation of the energy system

- Several projects for new pumped storage plants in development (up to 5 GW)
- Largest project is the Atdorf pumped storage plant (1,400 MW, approx. 13 GWh)

➡ Significant increase in storage capacity

In focus are also unconventional pumped storage plants

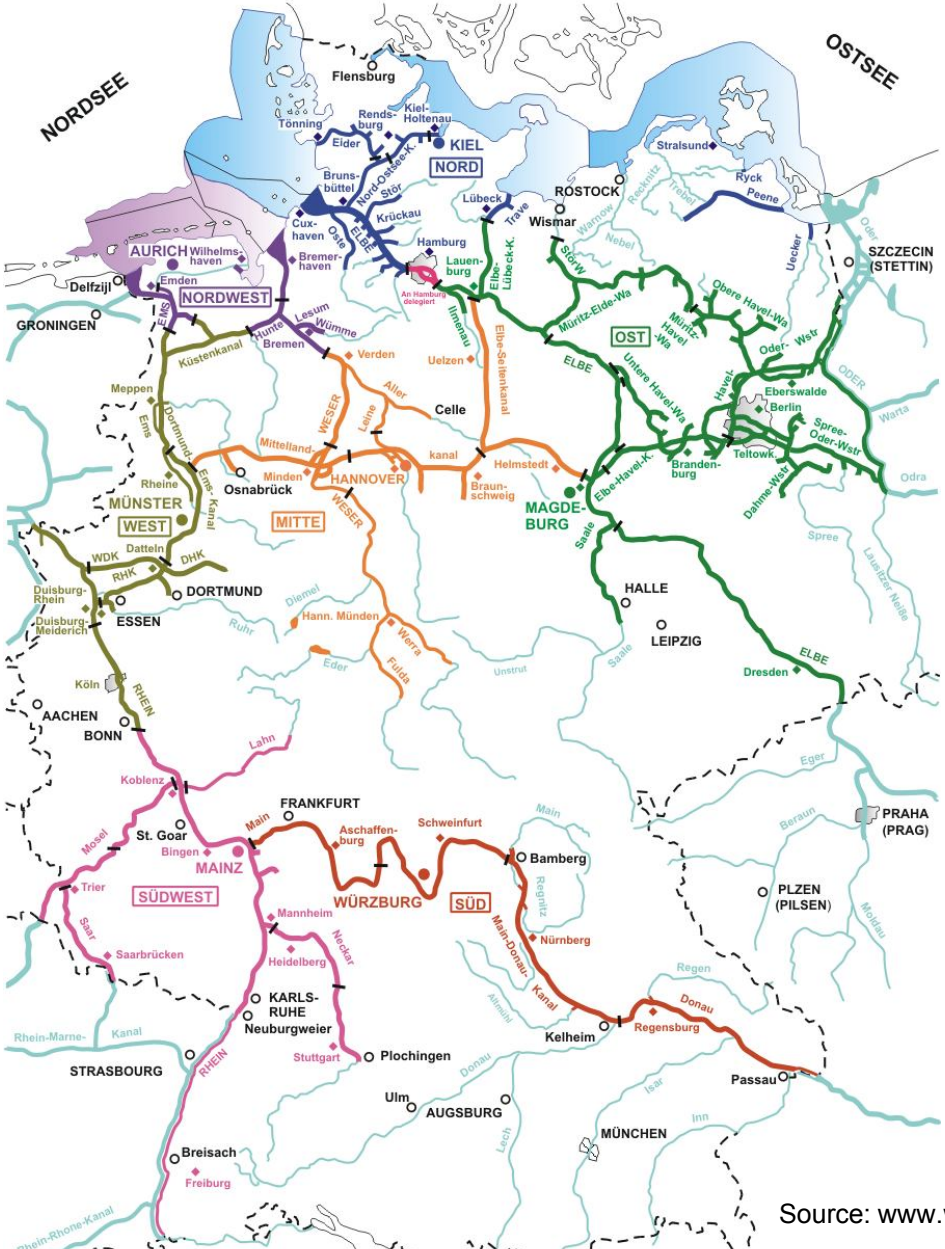
➡ Evaluation of the storage potential of federal waterways and identification of suitable sites

Basic principle

View of ship lift Lüneburg

Source: www.tage-der-industriekultur.de

Federal waterways in Germany



Source: www.wsv.de

- Federal waterways consist of rivers, canalized rivers, and **canals**

  Total length: 7,235 km

  Number of locks: 326

- Locks at rivers have usually a small elevation difference and are often equiped with run-off river plants

  ➡ Canals are most interesting for pumped storage plants

Total length of canals: 1,755 km

Analysed length: 1,340 km

Elevation difference: 611 m at 64 locks

Characteristics

- Longest canal pound: 174.2 km (Mittellandkanal)
- Max. useable water volume: 1.6 Mio. m³ (Mittellandkanal)

  ➡ Comparable to medium scale conventional pumped storage plants

- Relatively low elevation difference: < 1 m to max. 38 m (ship lift Lüneburg)

  ➡ Limiting factor regarding the storage capacity

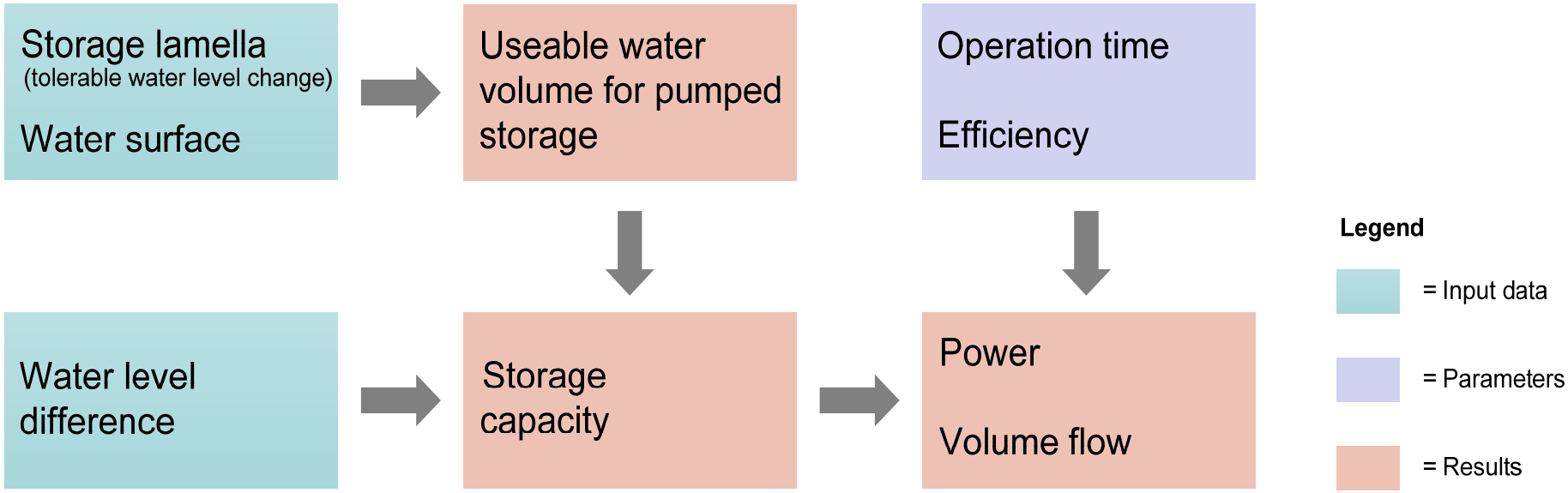
- Large synergies with existing infrastructure like reservoirs and pump stations (partially)

  ➡ Limited effort for pumped storage modification

- Absolute priority of shipping purposes

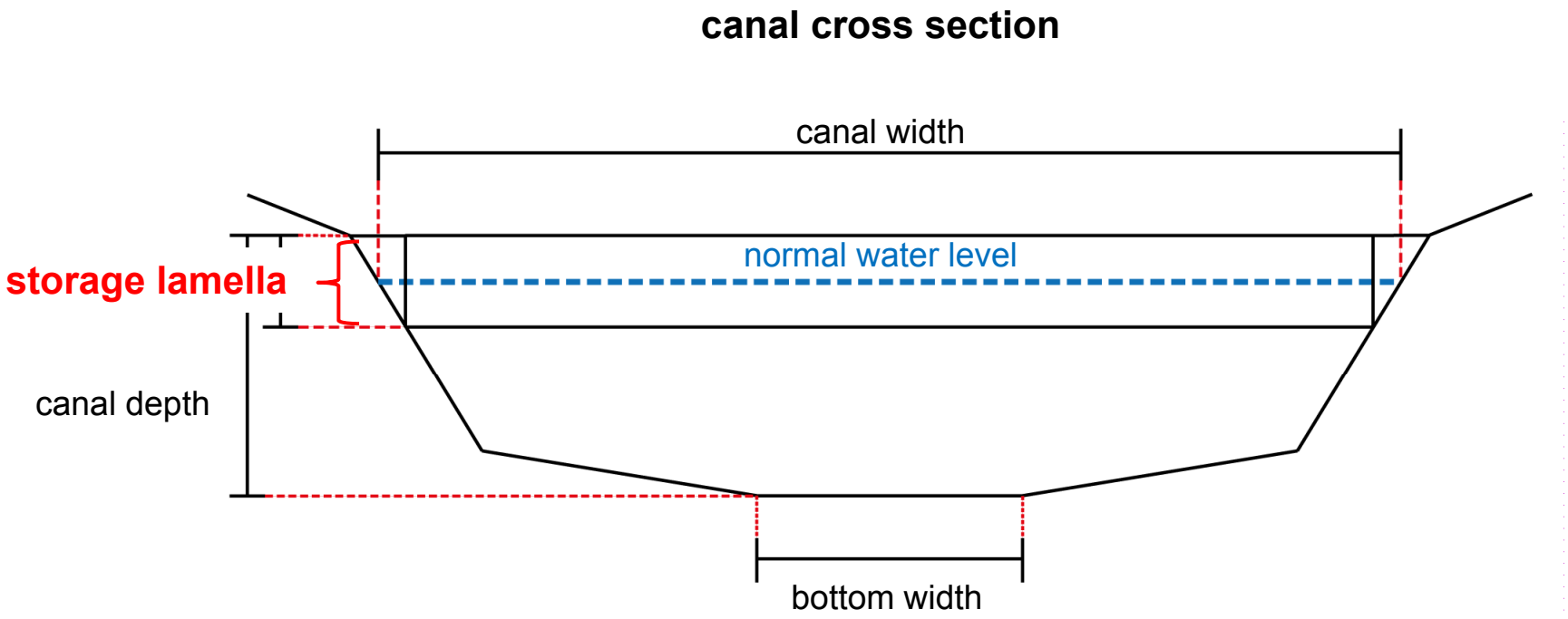
  ➡ All other uses are subordinated

Methodology for the potential evaluation



- Input data has been provided by the federal water and shipment administration (WSV – Wasser- und Schifffahrtsverwaltung des Bundes) and supplemented by own assumptions and calculations

Definition of storage lamella

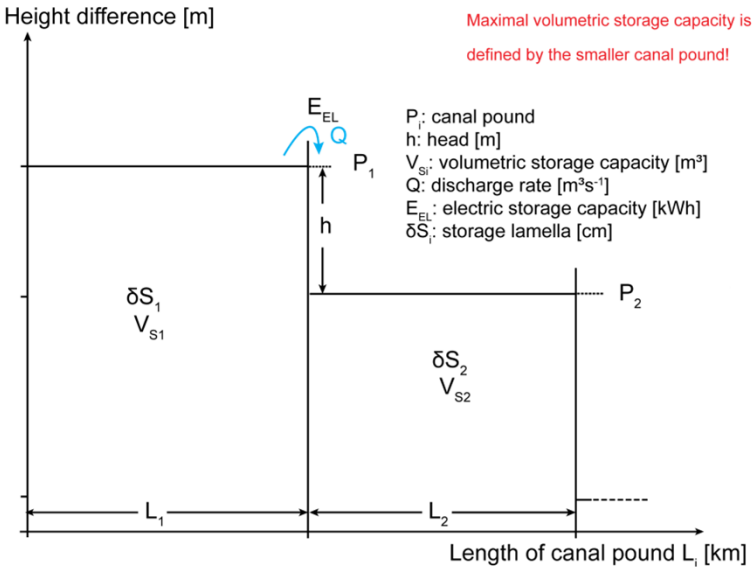


- Tolerable water level change due to canal water management (defined by WSV)
- Use of full storage lamella for pumped storage not applicable due to shipping purposes
- Assumption for potential evaluation: 50 % of storage lamella useable

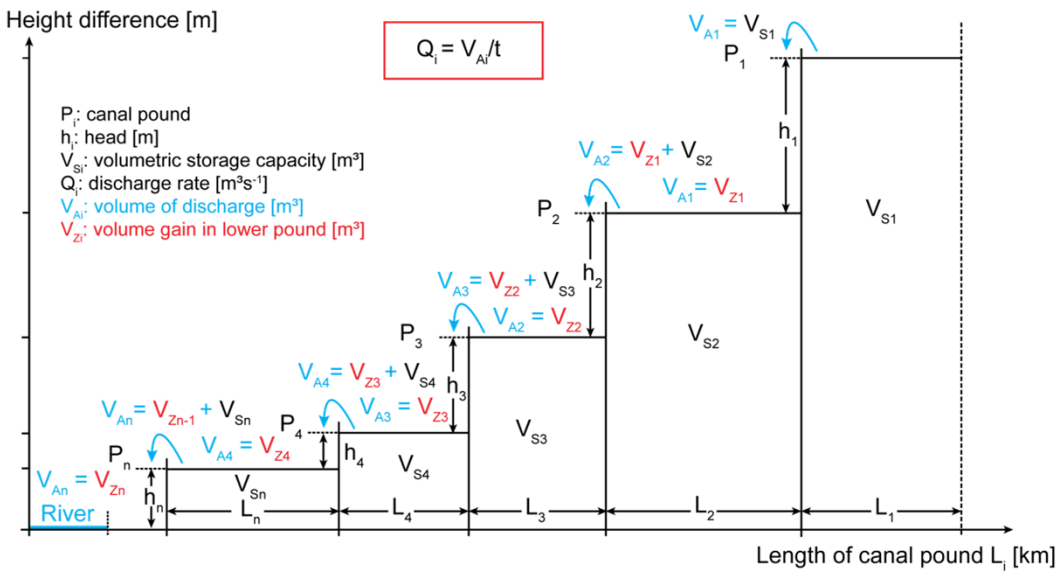
System configurations

Differentiation between two system configurations

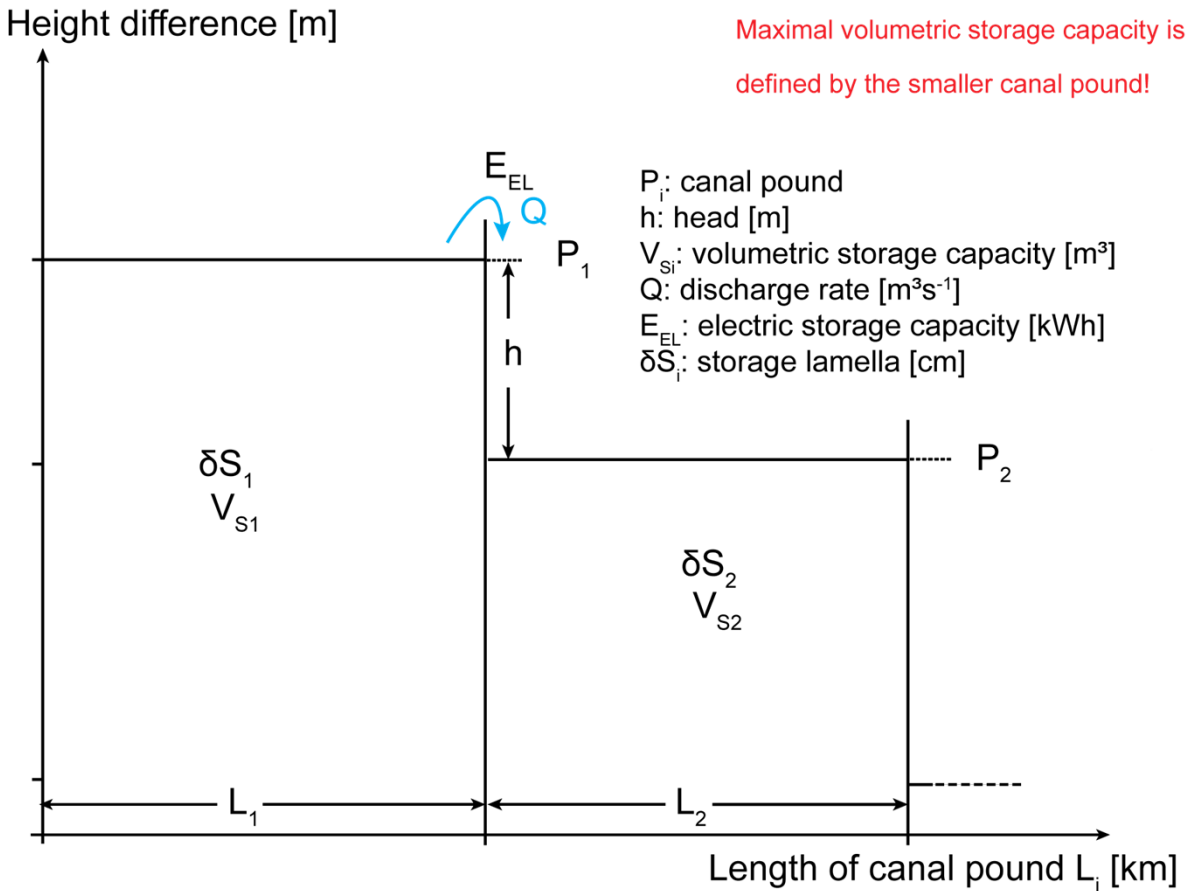
1. Lock pairs



2. Lock chains

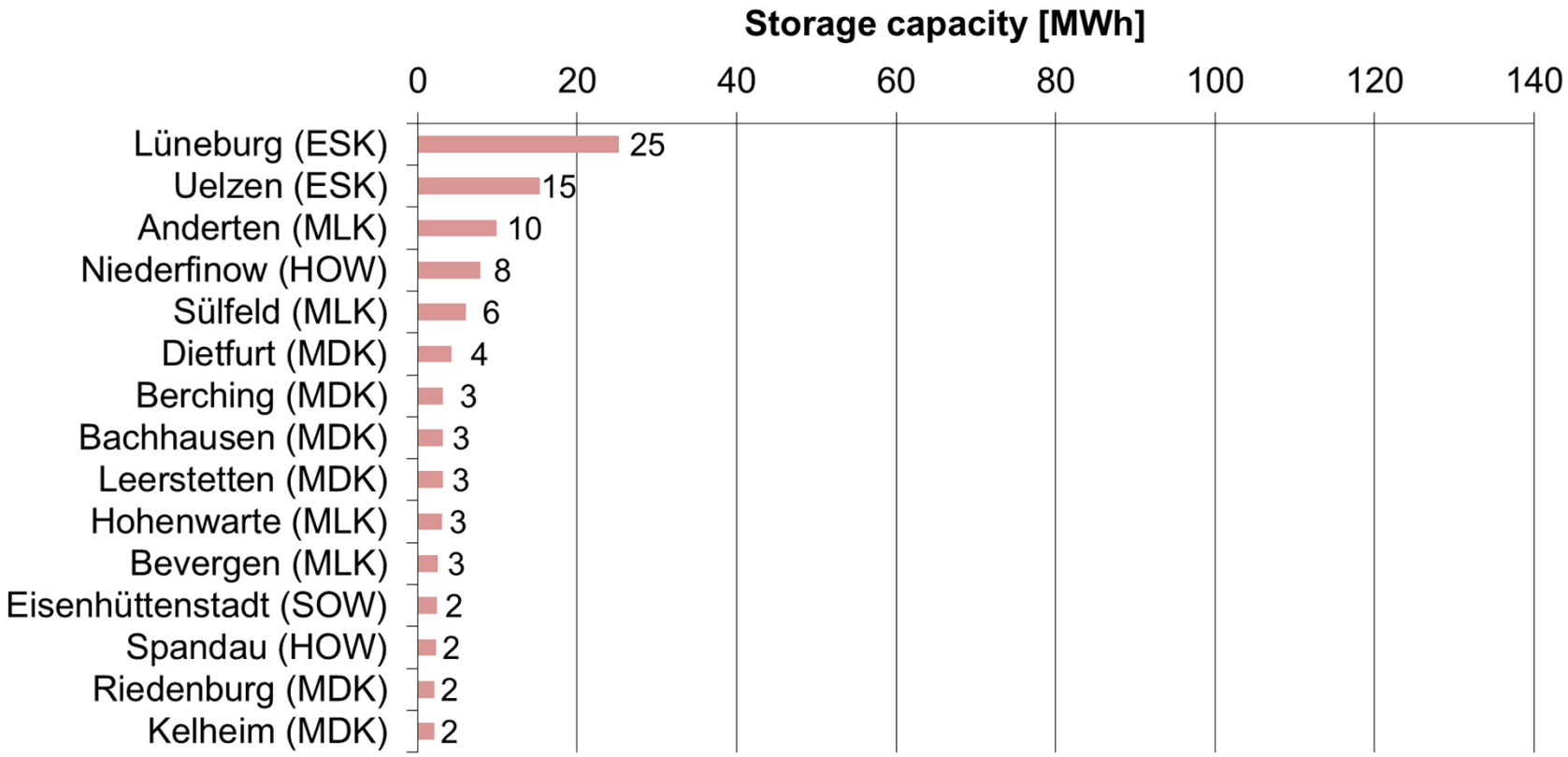


Potential of lock pairs



- Use of adjacent canal pounds to one single lock / ship lift
- Storage capacity is limited by the smaller canal pound

Ranking of lock pairs



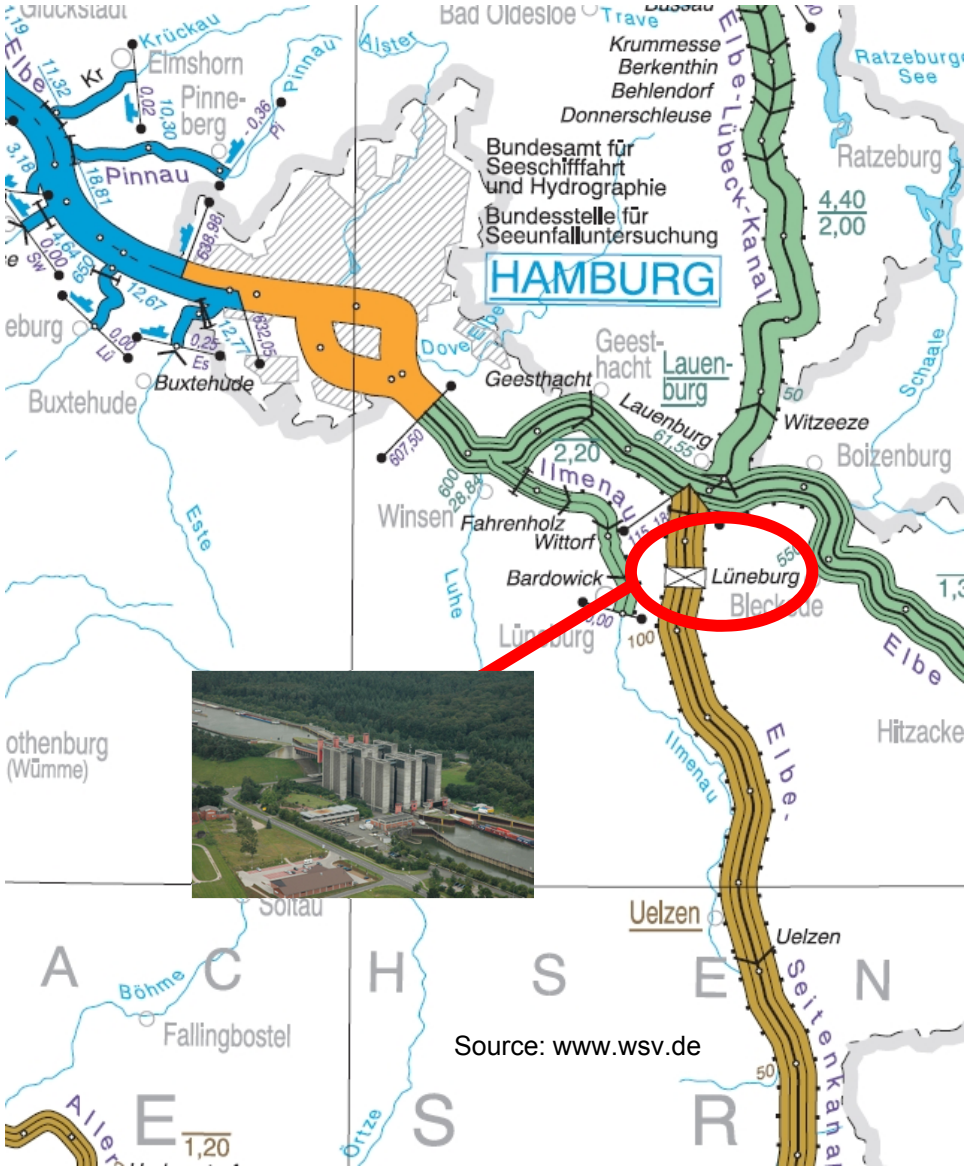
ESK: Elbe-Seitenkanal MLK: Mittellandkanal MDK: Main-Donau-Kanal

HOW: Havel-Oder-Wasserstraße SOW: Spree-Oder-Wasserstraße

- Overall: 22 lock pairs with storage capacity > 1 MWh

  ➡ Small scale installations with a limited storage capacity

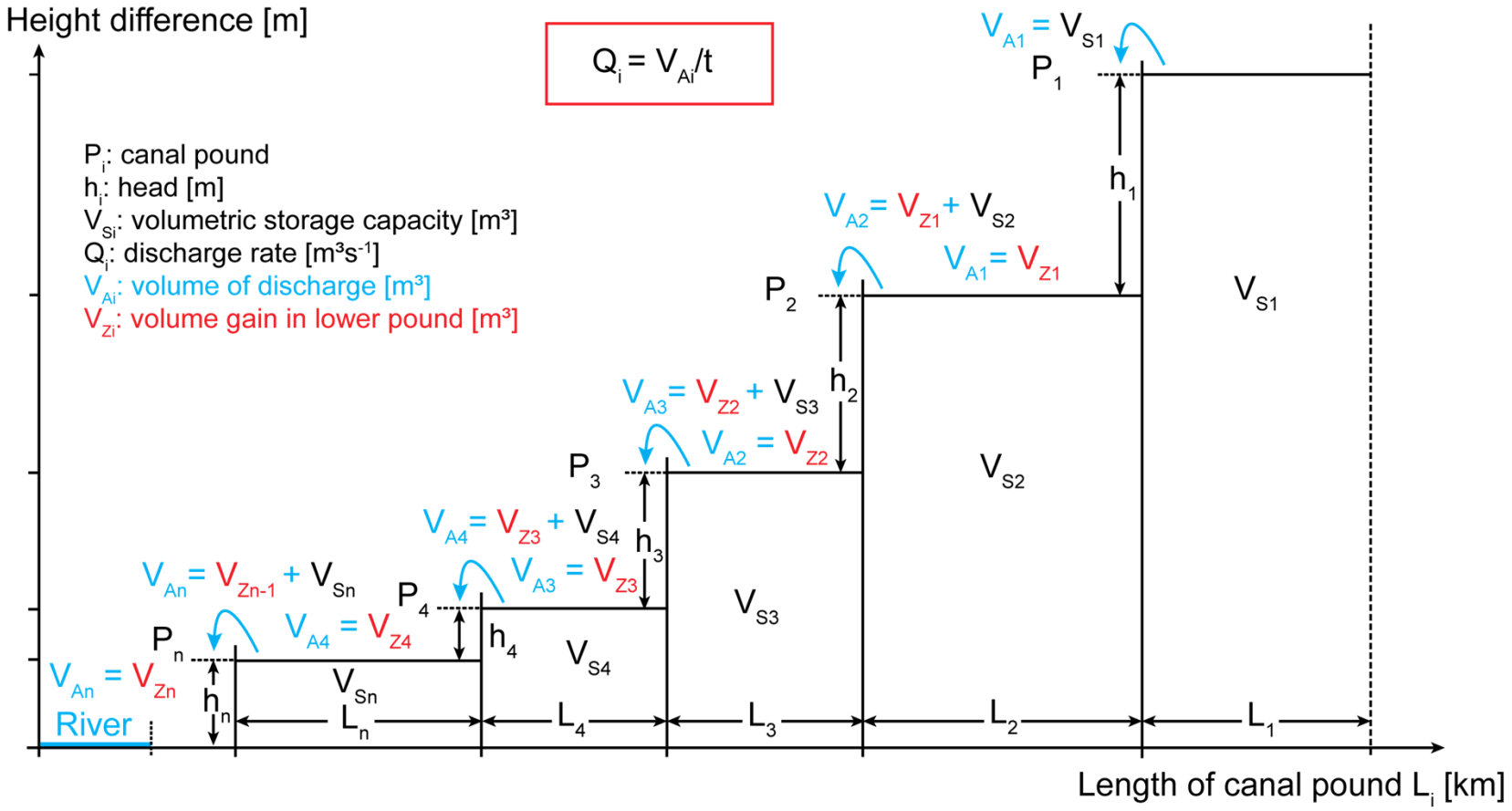
Spotlight: Ship lift Lüneburg



Source: www.wsv.de

- Max. elevation difference: 38 m
- Length of upper pound 45.5 km (between ship lift Lüneburg and lock Uelzen)
- Lower pound directly connected to river Elbe
- Storage lamella: 25 cm -> 12.5 cm considered
- Useable water volume for pumped storage: approx. 300,000 m³
- Capacity: 25 MWh, 6 h (assumed operation time) -> 4.2 MW, 14 m³/s
- Storage density: 0.084 kWh/m³ *(Goldisthal: 0.71 kWh/m³)*

Potential of lock chains



- Use of several locks and canal pounds in a row (once-through operation)
- Synchronous operation of pumps / turbines at all locks
- Increasing discharge volume and discharge rate after each pound

Potential of lock chains

#	Name	Length [km]	Locks [#] (*)	∑ Head [m] (*)	⌀ Head / lock [m/#] (*)
1	**Elbe-Seitenkanal (ESK)**	**115**	**2**	**61**	**30.5**
2	**Main-Donau-Kanal (MDK)**	**171**	**16**	**242.9**	**15.2**
3	**Mittellandkanal (MLK)**	**326**	**3 (14)**	**42.8 (132.7)**	**14.3 (9.5)**
4	**Wesel-Datteln-Kanal (WDK)**	**60**	**6**	**44.3**	**7.4**
	Selection criteria: ⌀ Head / lock > 7 m				
5	Rhein-Herne-Kanal (RHK)	45	5	34.5	6.9
6	Dortmund-Ems-Kanal (DEK)	226	10 (15)	67.7 (78.8)	6.7 (5.3)
7	Nord-Ostsee-Kanal (NOK)	99	2	9.9	5
8	Elbe-Havel-Kanal (EHK)	55	2	9.3	4.6
9	Datteln-Hamm-Kanal (DHK)	47	2	6.8	3.4
10	Finowkanal (FiK)	32	12	36.1	3

*:incl. branch and side canals and impounded river parts

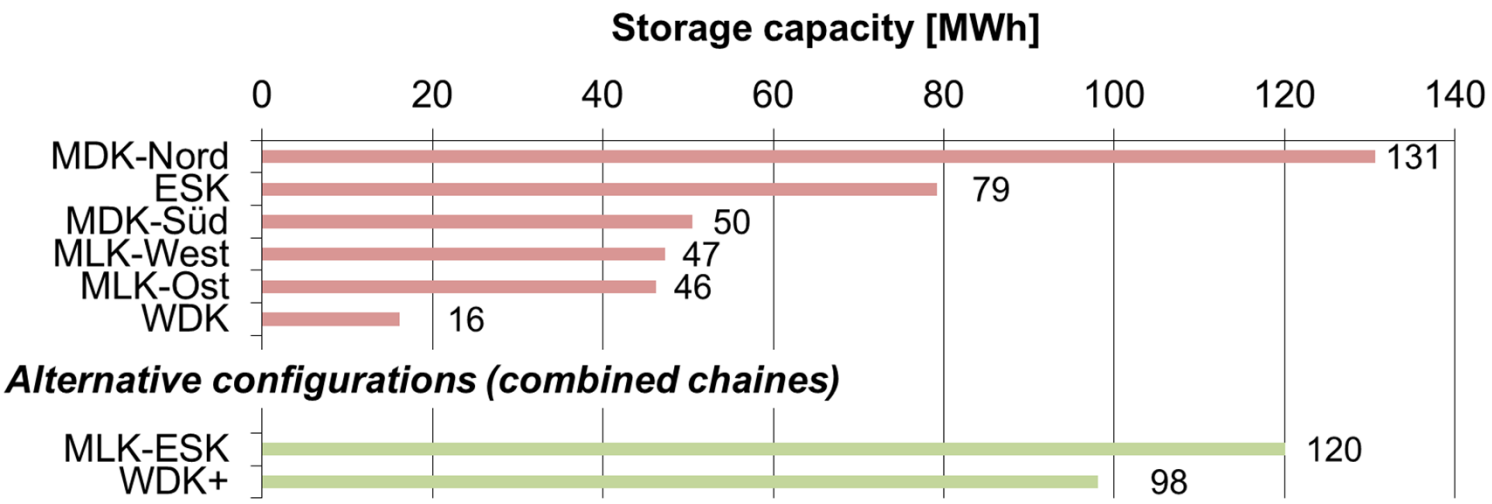
Site criteria for pumped storage installations at lock chains:

- *High elevation difference*
- *Low number of locks*

➡ 4 canals with ⌀ Head / lock > 7 m

➡ Other canals not considered for lock chains

Potential of lock chains



ESK: Elbe-Seitenkanal

MLK: Mittellandkanal

MDK: Main-Donau-Kanal

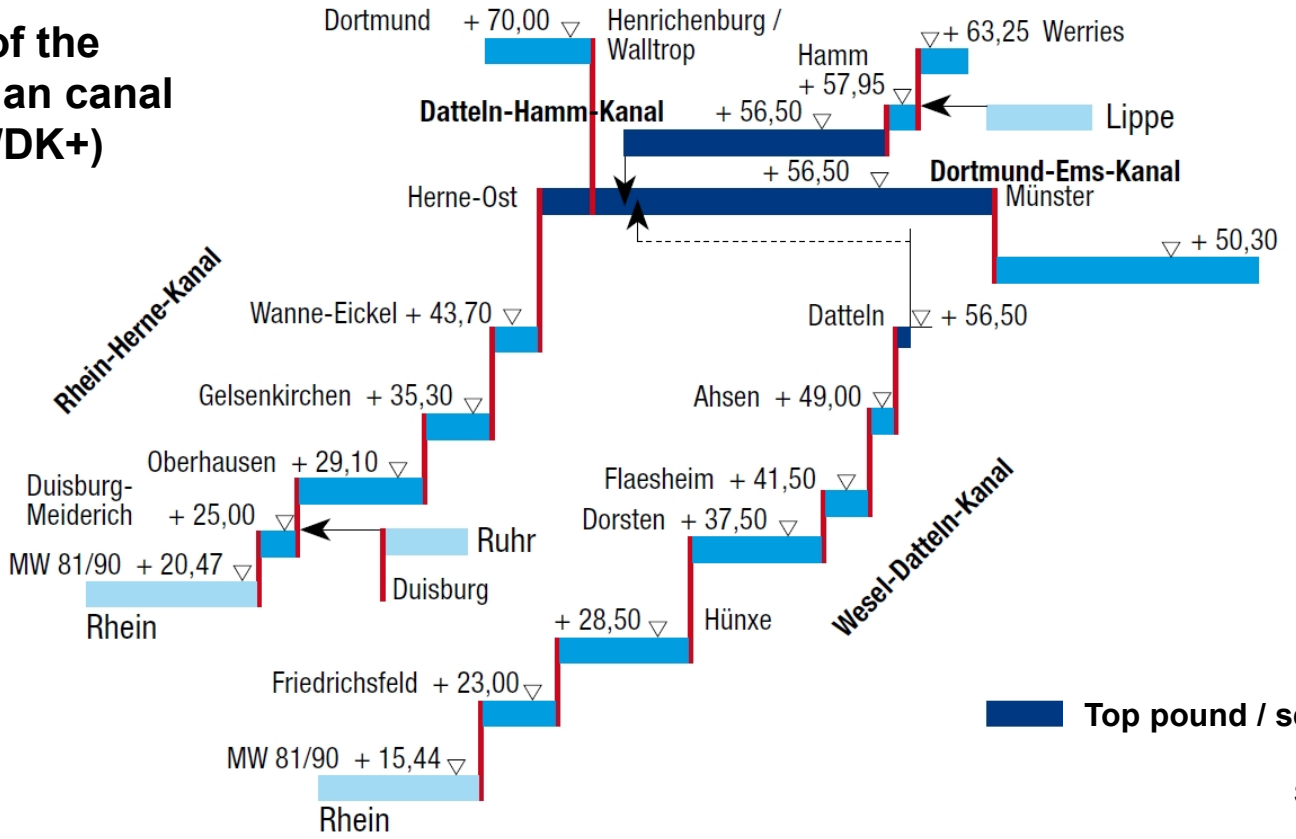
WDK: Wesel-Datteln-Kanal

WDK+: WDK inclusive west german canal cross at Datteln

- Significant increase of storage capacity compared to single lock use
- Higher system complexity due to incorporation of multi stage lock systems
- Occurence of high volume flows up to > 50 m³/s in the lower stages

Water management aspects

The case of the west-german canal system (WDK+)



Source: WSV, 2010

- Water demand of top pound > 500 Mio. m³/a due to lock operation and losses
- Water supply by the rivers Lippe, Ruhr and Rhein
- Pumping capacity for water management at WDK locks between 13.8 and 25 m³/s

Cost aspects

- Costs for pumped storage plants at federal waterways are very site specific

- No costs for the building of reservoirs and high pressure hydraulic installations

  ➡ Main cost component of conventional pumped storage plants

- Pump stations already existing at several locks

  ➡ Additional equipment or modification with turbines or pump-turbines possible

- High efficient pump-turbines for low head (7 - 38 m) and medium water volumes (10,000 – 1,000,000 m³) required

- Cost benchmark for new pumped storage plants: 850 €/kW

  ➡ 4.2 MW at ship lift Lüneburg: 3.6 Mio. € for pump storage modification tolerable

Summary and Outlook

- Pumped storage plants at federal waterways will be small scale plants but there are large synergies with existing infrastructure (e.g. reservoirs and pump stations)

  ➡ Availability and costs of high efficient pump-turbines (low head, medium volume flow)?

- Overall storage potential for Germany approx. 400 MWh or 1 % of installed capacity
- Most promising sites for pumped storage installations can be found at the *Elbe-Seitenkanal (ship lift Lüneburg, lock Uelzen)* in the northern part of Germany

  ➡ This site is characterized by a high power potential which is distributed over only a small number of locks

- Absolute priority of shipment purposes has to be considered

  ➡ Individual / site-specific assessment and definition of water availability for pumped storage operation and integration into water management systems required

Sources

Picture of ship lift Lüneburg
http://www.tage-der-industriekultur.de/locations/41

Map of federal waterways in Germany
http://www.wsv.de/wasserstrassen/gliederung_bundeswasserstrassen/karte/index.html

WSV, Wasserverband Westdeutsche Kanäle, Speisung des westdeutschen Kanalnetzes (Flyer), 2010

Basis data of waterways:

Various sources provided by WSV or local authorities